

CLAIMS

1. A solid-state imaging device comprising:
  - a plurality of light-receiving sections which are disposed in a substrate and which generate charge in response to incident light;
  - a planarizing layer which covers predetermined elements disposed on the substrate to perform planarization;
  - a plurality of signal lines disposed above the planarizing layer; and
  - a waveguide which guides incident light to each of the light-receiving sections, the waveguide passing through the space between the plurality of signal lines.
2. The solid-state imaging device according to Claim 1, wherein the waveguide comprises a light-transmissive material disposed in a hole formed by etching an insulating layer disposed on the substrate, and the waveguide includes a tapered portion in which the size of the planar shape viewed from the direction of incident light decreases from the light incident side surface toward the light-receiving section
3. The solid-state imaging device according to Claim 2, wherein a part of a side face of the waveguide covers an upper surface of at least one signal line among the plurality of signal lines.

4. The solid-state imaging device according to Claim 2, wherein the tapered portion is disposed according to the placement of the plurality of signal lines disposed adjacent to the light-receiving section.

5 5. The solid-state imaging device according to Claim 1, wherein the waveguide includes a first slope which inclines such that the size of the planar shape of the waveguide gradually decreases from the light incident side toward the side of the signal line, and one of a non-sloping part which 10 is not inclined and a second slope which inclines at an angle that is different from that of the first slope.

6. The solid-state imaging device according to Claim 5, wherein the first slope has an angle of inclination according to the positional relationship between at least 15 two signal lines among the plurality of signal lines, the at least two signal lines being disposed at different heights.

7. The solid-state imaging device according to Claim 5, wherein at least one signal line among the plurality of signal lines is disposed such that the end thereof overhangs 20 above the light-receiving section.

8. The solid-state imaging device according to Claim 1, wherein the waveguide has a first side face and a second side face, the first side face and the second side face having different shapes.

25 9. The solid-state imaging device according to Claim 8,

wherein the first side face includes a plurality of slopes having different angles of inclination.

10. The solid-state imaging device according to Claim 9, wherein at least one slope among the plurality of slopes has 5 an angle of inclination according to the positional relationship between at least two signal lines among the plurality of signal lines, the at least two signal lines being disposed at different heights.

11. The solid-state imaging device according to Claim 8, 10 wherein at least one signal line among the plurality of signal lines is disposed such that the end thereof overhangs above the light-receiving section.

12. A method for fabricating a solid-state imaging device comprising:

15 a step of forming an insulating film on a substrate provided with a light-receiving section; a step of forming an opening in the insulating film at a position corresponding to the light-receiving section; and a step of forming a waveguide by embedding a light- 20 transmissive material in the opening so that the waveguide can guide incident light from outside to the light-receiving section,

wherein in the step of forming the opening, a resist layer is formed in a forward tapered shape during 25 photoresist patterning for forming the opening, and the

forward tapered shape is transferred during the formation of the opening by etching so that the opening has a forward tapered portion in which the size of the planar shape viewed from the direction of incident light decreases from the 5 light incident side surface toward the light-receiving section.

13. A method for fabricating a solid-state imaging device comprising:

a step of forming an insulating film on a substrate 10 provided with a light-receiving section;  
a step of forming an opening in the insulating film at a position corresponding to the light-receiving section; and  
a step of forming a waveguide by embedding a light- 15 transmissive material in the opening so that the waveguide can guide incident light from outside to the light-receiving section,

wherein in the step of forming the opening, an etching process is performed to form the opening under the etching conditions such that a forward tapered shape is formed by 20 inhibiting isotropic etching, and thereby the opening has a forward tapered portion in which the size of the planar shape viewed from the direction of incident light decreases from the light incident side surface toward the light-receiving section.

25 14. The solid-state imaging device according to Claim 1,

wherein the waveguide includes a plurality of layers having different diameters, and in the two adjacent layers among the plurality of layers, the lower diameter of the upper layer is set smaller than the upper diameter of the lower

5 layer.

15. The solid-state imaging device according to Claim 14, wherein at least one layer among the plurality of layers has a tapered sidewall.

16. A method for fabricating a solid-state imaging device provided with a hole disposed above a light-receiving section, the hole including a low-refractive-index layer and a high-refractive-index layer embedded in the low-refractive-index layer, the method comprising a step of forming the low-refractive-index layer covering the surface, 15 forming an opening in the low-refractive-index layer, and embedding the high-refractive-index layer in the opening, the step being repeated a plurality of times to form the hole.

17. The method for fabricating a solid-state imaging device according to Claim 16, wherein in the plurality of times of the step, the lower diameter of the opening formed in a step is set smaller than the upper diameter of the opening formed in its preceding step.

18. The method for fabricating a solid-state imaging device according to Claim 16, wherein among the openings

formed in the plurality times of the step, at least one opening is formed so as to have a tapered sidewall.

19. The solid-state imaging device according to Claim 1, wherein the waveguide comprises a light-transmissive film 5 having a relatively high refractive index, the light-transmissive film being embedded in a hole formed by etching an insulating film having a relatively low refractive index, the light-transmissive film includes a first material portion containing at least hydrogen, and the light- 10 receiving section contains hydrogen released from the first material portion by heat treatment in a hydrogen atmosphere.

20. The solid-state imaging device according to Claim 19, wherein the first material portion comprises silicon nitride formed by plasma CVD.

15 21. The solid-state imaging device according to Claim 19, wherein an etching stopper film for forming the hole is provided on the upper surface of a gate-insulating film on the light-receiving section, and the first material portion is in contact with the gate-insulating film through an 20 opening of the etching stopper film.

22. The solid-state imaging device according to Claim 21, wherein the etching stopper film comprises silicon nitride formed by low-pressure CVD.

23. The solid-state imaging device according to Claim 21, 25 wherein the etching stopper film at least extends to above a

transistor region provided in the substrate in the periphery of the light-receiving section.

24. The solid-state imaging device according to Claim 19, wherein the first material portion has an opening at the top, 5 and a second material portion having a refractive index lower than that of the first material portion is disposed in the opening.

25. The solid-state imaging device according to Claim 24, wherein the second material portion comprises a synthetic 10 resin material.

26. The solid-state imaging device according to Claim 25, wherein the synthetic resin material is a polyimide resin.

27. A method for fabricating a solid-state imaging device comprising a photoelectric conversion section disposed in a 15 semiconductor substrate, an upper-layer film disposed on the semiconductor substrate with a gate-insulating film therebetween, a hole formed so as to extend from the upper surface of the upper-layer film to the gate-insulating film on a light-receiving region of the photoelectric conversion 20 section, and a waveguide embedded in the hole, the method comprising:

25 a step of embedding a first high-refractive-index material containing hydrogen constituting at least a part of the waveguide in the hole formed in the upper-layer film; and

a step of releasing hydrogen from the first high-refractive-index material toward the photoelectric conversion section by subjecting the first high-refractive-index material to heat treatment in a hydrogen atmosphere.

5 28. The method for fabricating a solid-state imaging device according to Claim 27, wherein the first high-refractive-index material is formed by plasma CVD of silicon nitride.

29. The method for fabricating a solid-state imaging  
10 device according to Claim 27, further comprising:

    a step of forming an etching stopper film on the semiconductor substrate provided with the photoelectric conversion section and the gate-insulating film;

15   a step of forming the upper-layer film on the etching stopper film;

    a step of forming the hole by etching the upper-layer film; and

    a step of removing the etching stopper film remaining on the bottom of the hole.

20 30. The method for fabricating a solid-state imaging device according to Claim 29, wherein the etching stopper film is formed by low-pressure CVD of silicon nitride.

31. The method for fabricating a solid-state imaging device according to Claim 29, wherein a silicon nitride film  
25 constituting the etching stopper film is allowed to remain

in a region other than the light-receiving region of the semiconductor substrate.

32. The method for fabricating a solid-state imaging device according to Claim 29, wherein a silicon nitride film which is allowed to remain in a region other than the light-receiving region is allowed to remain in a region that covers at least a part of or all of a plurality of transistors disposed in the semiconductor substrate.

33. The method for fabricating a solid-state imaging device according to Claim 32, wherein the silicon nitride film which is allowed to remain in the region other than the light-receiving region is allowed to remain in a region that covers at least transistors disposed in the periphery of the photoelectric conversion section.

34. The method for fabricating a solid-state imaging device according to Claim, wherein the silicon nitride film which is allowed to remain in the region other than the light-receiving region is disposed between a gate electrode of the transistor and a signal line disposed in a layer above the gate electrode.

35. The method for fabricating a solid-state imaging device according to Claim 27, further comprising forming an opening in the top of the first high-refractive-index material of the waveguide, and disposing a second high-refractive index material in the opening.

36. The method for fabricating a solid-state imaging device according to Claim 35, wherein the refractive index of the first high-refractive-index material is higher than the refractive index of the second high-refractive-index material, and the refractive index of the second high-refractive index material is higher than the refractive index of the upper-layer film.

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